ASPHALT INSTITUTE *Quarterly*

OCTOBER 1951

THE NEW JERSEY TURNPIKE

Heavy black line on map shows route of the Turnpike. White lines designate U. S. and State Highways. The map scale is approximately sixteen miles to one inch.

ASPHALT INSTITUTE *Quarterly*

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The names of the Member Companies of the Institute, who have made possible the publication of this magazine, are listed herein on page 15.

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New Jersey Turnpike Issue

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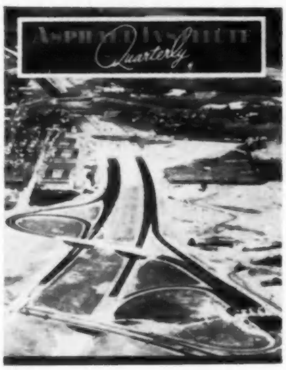


COVER

Featured on the covers is a construction photo, air-view by Ostergaard, of the Route 35 Traffic Interchange, near Woodbridge and the Amboys. Here, four lanes of asphalt widen to six and lead toward New York City's tunnel and bridge approaches. Over-passes and under-passes, as shown, together with acceleration and deceleration lanes, make for a continuous traffic flow.

The Map opposite shows the New Jersey Turnpike as a "corridor" between points to the North and East and points to the South and West. In important addition, however, it features (with its black squares) many Traffic Interchanges, so placed as to connect with Federal and State Highways to foster the growth and development, in its entirety, of this the nation's second most densely populated state.

EDITORIAL

This November will see substantial completion of the New Jersey Turnpike — one of the *largest* single highway projects ever constructed. This Turnpike is notable, too, for its record speed of construction, as reported in this issue; for financing through revenue bonds on a forward commitment basis; and for the selection of the *asphalt pavement type* for its entire length, following competitive bidding which showed a saving of over $5,000,000 in favor of the approved asphalt design.

The successful outcome of this project undoubtedly will lead to similar planning in other locations. While it will be possible to salvage many thousands of miles of existing highways through a process of widening, resurfacing, and revision of short sections to improve alignment and grade, there is a limited mileage in and adjacent to metropolitan areas where the only solution is complete reconstruction. Piecemeal improvement in areas of very dense traffic only makes a bad matter worse, because it invites increased use of the new short sections, thereby creating two bottlenecks where but one existed before. The traffic picture as a whole must be most carefully examined and the improvement not only should provide for safe, regulated flow throughout the entire length of the project itself, but it must also include appropriate traffic distribution at terminals and points of access and exit. This requires engineering of the highest order and is a field in which the private consulting engineer and the state highway engineer should pool their talents.

The conventional method of allocating state highway funds appears at present inadequate to the needs of some of these special situations. While it would seem that a state might so plan that needed large projects could be finished in a short space of time from the state road fund, and at presumably somewhat lower rates of interest, there often are handicaps of area competition which delay early legislative approval, if it may be obtained at all. Hence it is but practical to consider alternate procedures whereby sufficient income is produced from the project itself. Just what kind of plan is best suited for each particular development is the subject of much debate. If a state bond issue can be secured, this will be usually a first preference but, if a state-created turnpike authority is the only practicable alternative, it would seem desirable where traffic volumes are sufficient to make the project completely self liquidating.

Taking bids on alternate pavement types is a subject too, on which there is some difference of opinion. Competition between various materials is intense, but is desirable as it has resulted in lower costs and improved quality. On small projects local conditions are so well understood that usually one type has an advantage, and preliminary estimates which indicate a saving of as much as 20%, will lead usually to adoption of that type alone in the bidding. For larger projects, such as these new turnpikes, where vast quantities of materials are required and where it is practicable to use the most efficient machinery regardless of first cost, the only way to determine the relative economy of several pavement types is to take alternate bids. This affords contractors an opportunity to utilize to the full both experience and the most modern road-building equipment.

It appears from the record that all of the foregoing has been given full consideration by the New Jersey Turnpike Authority and its engineers.

Construction on the 118-mile New Jersey Turnpike, August 25, 1951, with swift completion and pleasant motoring in November just ahead.
From Roosevelt Avenue Bridge. Photo: Ostergaard

THE NEW JERSEY TURNPIKE

One of America's Heaviest-Duty Highways

By Herbert Spencer, *District Engineer, The Asphalt Institute*

The many articles that have appeared in newspapers, magazines, and particularly the Engineering journals have described the inception and the progress of work on the New Jersey Turnpike. Because of its magnitude, this project is of definite interest to all highway builders, to the asphalt industry, and to those forward-looking engineers who see in this Turnpike the answer to certain economic and design problems that have beset road builders for many years. The New Jersey Turnpike is of asphalt construction, laid on a flexible base, and is in agreement with the design principles that the Asphalt Institute has enunciated previously, both in this magazine and in its other publications. It is one of the longest asphalt highways ever constructed as a single project, and one of the most important privately financed Turnpikes yet undertaken. Some of the highlights of this project, including methods of financing, traffic studies, design details, and other items of interest are presented herewith.

The New Jersey Turnpike is a *toll road* traversing the State of New Jersey from a point on the Delaware River where the Delaware Memorial Bridge has only recently been opened, northward to the approaches to the George Washington Bridge at New York City, a distance of 118 miles. It parallels New Jersey Route #25 (U. S. Route #1), one of the heaviest traveled highways in the United States, and is intended to relieve the present congestion thereon. Lying between the great industrial centers of New York City and Philadelphia, New Jersey has been referred to as "The Corridor State." While the existing system of highways carries the very heavy traffic between these two cities, as well as from the South and West, it has been apparent for some years that these State and County Highways had become quite inadequate to provide properly for present and future needs.

A CONGESTED TRAFFIC AREA

It has been estimated that some 265,000 vehicles move daily in a north-south direction in the northern New Jersey area, and of this total as many as 110,000 have been recorded on U. S. #1 in the vicinity of the Newark Airport. It is anticipated then that the Turnpike, together with the New Jersey #4 Parkway now under construction and other projected State Highways, will ultimately relieve this situation, particularly the present wasteful and intolerable truck traffic congestion.

It was in October 1948 that the New Jersey State Legislature authorized the creation of a Turnpike Authority, and in March 1949 the Governor appointed Paul L. Troast as Chairman, George F. Smith as Vice Chairman, and Maxwell Lester, Jr. as Treasurer. Charles M. Noble, previously Chief Engineer of the New Jersey Highway Department, was appointed Chief Engineer for the Turnpike Authority.

One of the first acts of the Authority was designation of a group of seven Consulting Engineers to make the necessary engineering studies, to expedite planning and pro-

ESTIMATED RESULTS OF OPERATION OF THE NEW JERSEY TURNPIKE

YEAR	VEHICLES	VEHICULAR REVENUE	CONCESSION REVENUE $7\frac{1}{2}\%$	TOTAL REVENUE	OPERATING EXPENSES	BALANCE AVAILABLE FOR DEBT SERVICE
1952	7,600,000	$ 7,150,000	$ 536,000	$ 7,686,000	$1,500,000	$ 6,186,000
1962	15,000,000	14,300,000	1,072,000	15,372,000	1,500,000	13,872,000
1972	20,000,000	19,300,000	1,448,000	20,748,000	1,500,000	19,248,000
1975	21,500,000	20,800,000	1,560,000	22,360,000	1,500,000	20,860,000

vide for early lettings of the entire length of the Turnpike. Grading and bridge abutment contracts were let in 1949 and early 1950 as quickly as plans and contracts could be prepared. The opening date was scheduled for November 1951, and the rapid rate of operations in meeting this date has made this project one of the speediest highway construction jobs ever completed.

Coincident with the engineering studies were the plans for the financing. These were related of course both to the engineers' estimates of cost, and to traffic studies to evaluate potential revenues. The combined engineering estimate was submitted by the consulting engineers in September 1949 and indicated a total project cost of $230,000,000. The results of traffic studies, based on the reports of Coverdale and Colpitts, are partly shown in the table on page 4 and forecast the expected increase in revenues between 1952 and 1975, together with operation cost. These studies, in their entirety, indicate that a bond issue of $230,000,000 would be amortized by 1975 or within a period of 24 years after the opening of the Turnpike to traffic.

ENGINEERING PROBLEMS

The southern portion of 87.2 miles from the Delaware River to a point east of New Brunswick offered no unusual handicaps to rapid construction. Route location was selected to by-pass all towns and cities and yet be close enough to afford easy access through selected interchanges. Over this southern portion practically no rock was found, cuts were not extreme, and consequently little difficulty was encountered in grading operation. Excellent supplies of stone, gravel and sand, found within easy trucking distances, were readily available for paving operations.

The northern portion of 30.1 miles, however, presented a totally different picture with extremely difficult problems, the solution of which called for the utmost engineering skill. Here the Turnpike cuts through the "Jersey marshes", a vast swampy area of varying widths and depths. These marshes through which sizable rivers meander are close to sea level. They also are crossed by several trunk line railroads and are close to the great industrial sections of Newark, Elizabeth, Jersey City, Hoboken, and many smaller communities. For years this expanse of Jersey marshland has been a challenge to engineers, its proximity to the industrial centers making it ideal for commercial use. While some highways cross these swamps, and some industrial plants have been established, the fear of constant settlement has so far barred extensive development. So when the Turnpike engineers boldly decided to place this important highway right through the worst section of these meadows, there was considerable lifting of

On a tight schedule, Turnpike traffic lanes and shoulders required in all 6,300,000 square yards of asphalt.
Approach to Lincoln Tunnel. Photo: Spencer

eyebrows, and dire predictions of what might happen.

Much has been written in engineering journals as well as by The Asphalt Institute on the stabilization of soils to provide adequate foundations. The engineers for the Turnpike of necessity kept before them the fact that their job was to design a major highway having potential moving loads of 36,000 pounds single axle weight. The fact that this settlement problem has been solved is a tribute to the skill of the engineers and is an outstanding feat in American engineering practice.

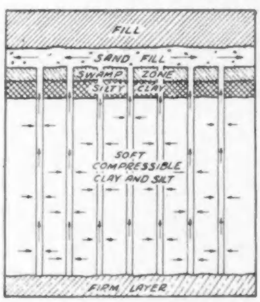
VERTICAL SAND DRAIN METHOD

Solution for the continued settlement was adoption of the sand-pile or rather *sand-drain*, so placed as to *accelerate* the drainage of water from the surrounding mud by forcing it laterally upward and outward when subjected to the pressure of the overlying fill. As the mud on these meadows reaches depths in excess of 100 feet, it was apparent that any ordinary fill would soon sink out of sight, and that permanent stability would be obtained only through placement of enormous quantities of material. Fills for ordinary depths are quite common; also the removal of muck and replacement with suitable material is often successful. Such methods, however, are limited to shallow swamp areas; for deep swamps the cost becomes prohibitive, and in many cases results in the formation of enormous mud waves—a condition the engineers must avoid.

The vertical sand-drain principle is an adaptation of the placing of drains on a slope subject to landslides, where the drain intercepts the horizontal flow of water and leads it off by gravity. In the case of a swamp, however, there is no slope, and hence a substitute for the pressure caused by gravity must be created. When a weight is placed on a saturated mass such as a wet sponge, the water is forced out and the sponge shrinks. If a porous pipe is inserted in this sponge, the pressure on the top will force the water into this pipe and upward where it can be led away. In the case of the New Jersey meadows the swamp is the sponge,

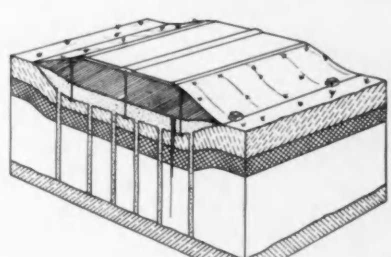
Continued on page 6

FILL STABILIZATION—VERTICAL SAND DRAIN METHOD



OPERATION OF SAND DRAINS

Diagram of water flow from the soft underlying clay and silt through the porous vertical drains and sand blanket.



FINAL STABILIZED ROADWAY

Showing compression of soft materials under embankments. Pore pressure devices and settlement platforms left for permanent record.

CONSTRUCTION VIEW OF ROUTE 3 — LINCOLN TUNNEL INTERCHANGE.
Air-Photo: Ostergaard

Continued from page 5

the sand-drain is the pipe and the heavy overlay of fill furnishes the pressure. This is all in accordance with the principles of sound soil mechanics, and its application on the New Jersey marshes has demonstrated its success to a greater extent than ever before.

The stabilization of the Jersey marshes in the quickest time to allow the roadway to be placed and opened to traffic was of the utmost importance. The muck contains a large percentage of water and the speed at which this is expelled from the soil is a measure of the consolidation, as theoretically the shrinkage is equivalent to the water displaced. This system of sand-drains used for the New Jersey Turnpike was designed and supervised by O. J. Porter & Company, one of the Consulting Engineer firms on the Turnpike. The various steps were as follows:—

A porous sand blanket was first placed about three feet thick to serve both to convey the water to the sides and as a working table for the contractors rig.

The sand-drain was next driven. This consisted of setting up and driving a mandrel averaging 14 inches in diameter placed between the leads of the rig and sunk to a depth determined by borings. This depth varied from fifteen to almost one hundred feet with spacings between drains governed by the depth of consolidation, or from five to fifteen feet apart.

The mandrel or pipe was next filled with clean sand, a pressure of approximately one hundred pounds per square inch being applied to the sand column, so that the mandrel could be withdrawn. A flap-valve at the bottom of the pipe allowed the sand to flow out and the mandrel was raised without difficulty.

The fill material was then placed in layers not exceeding six inches and thoroughly compacted. It was necessary to watch this placement carefully as too fast loading would result in some flow in the subsoil and the formation of mud-waves. When the critical height was reached, lifts not in excess of two feet per week were placed.

Pore pressure gauges were installed as a means of recording settlement at different levels and to show the pressure resulting from the loadings. The proper balance between loading and settlement was essential and was carefully watched. With such care uniform subsidence of over nine feet, under fills in excess of fifty feet depth, was secured in sections between the Passaic and Hackensack Rivers. Over the greater part of the marshland final settlement has been reached and the pavement is now in place.

In order to assist in this operation, overload material is placed in depths of from 5 to 12 feet, increasing the weight on the underlying mud, and forcing out the water at an accelerated rate. This overload material is removed after final settlement has been reached, and material constituting the subgrade of the pavement is then placed.

THE ASPHALT PAVEMENT

The type of pavement to be placed on the Turnpike was of course a most important item in the over-all design and in 1949 the Asphalt Institute, upon request, presented its views on the merits of the flexible base and asphalt type at a meeting before the Authority and their engineers on August 24, 1949. Our presentation emphasized the following important advantages:

1. LOWER INITIAL COST

In any consideration of comparative road surfaces, the item of cost, consistent with durability, is of first importance. The records of practically every State Highway Department in the country bear witness to the fact that flexible bases with asphalt surfaces can be built at considerably less cost than rigid type pavement, with saving usually of from 20% to 50%. In the case of the New Jersey Turnpike, this is true and can be attributed to:

A—Greater use of locally available materials, as compared to costly imported materials.

B—Less thickness of high-cost materials required, the wearing course of asphalt pavements being considerably thinner than required for rigid pavements.

C—Elimination of steel reinforcing, expansion and contraction joint materials, dowels or other load transfer materials not being required for asphalt pavements.

D—Elimination of forms.

E—Immediate availability of asphalt types as soon as laid, thus avoiding costly detours.

2. LOWER MAINTENANCE COST

Recent records available, particularly those of the last five years, show a distinct saving in maintaining asphaltic concrete pavements as compared to the rigid type. Inasmuch as the asphalt pavement maintains contact at all times with the foundation, and it in turn with the earth itself, the few repairs needed can be made direct to the surface with asphaltic material, rather than by slab replacement. Asphalt pavements are not affected by the salts used for snow and ice control and, being free of joints, asphalt pavements are not subject to the pumping action so often found in rigid construction.

3. DURABILITY

In considering highway design, emphasis must be placed equally on the foundation and the wearing course. Since the earliest days of asphalt road construction, engineers in all parts of the United States have studied the best methods of utilizing the locally available natural aggregates, either as component parts of an asphalt mixture, or as bases for an asphalt wearing course. The support provided by well designed, well consolidated flexible bases has been proven ample for present-day loads which so frequently have exceeded those originally contemplated.

The wartime history of asphalt pavements provides an outstanding service record. Access roads and airfields built in the United States and all over the world have stood up under the most gruelling traffic. At the General Motors and Chrysler proving grounds, asphaltic concrete was the only pavement that successfully withstood the shearing, tearing action of 50-ton tanks when being tested before shipment.

4. FLEXIBLE BASE

So far as the flexible base design is concerned, it of course is not new in this area, as such bases have been constructed, especially in New Jersey, over a long period. One of the most eminent road engineers in the United States at the turn of the present century was James Owens of Essex County, considered one of the pioneers in use of macadam roads. The stone bases and Telford foundations he built fifty years ago still serve as adequate foundations, indicating the value of granular materials for the support of the loads imposed.

DESIGN EXPLORATION

Shortly after appointment of the Consulting Engineers, a Pavement Committee was organized, made up of representatives from each consulting firm, with the assignment to formulate recommendations for the Turnpike pavement. The recommendations of the Asphalt Institute were fully reviewed by this group, and on June 12, 1950 their final report was issued. This was eminently fair to the advocates both of the asphalt type and the "concrete"type by placing the two in competition. The design for the flexible base asphalt top, as finally adopted, called for:

$4\frac{1}{2}''$ of asphaltic concrete pavement laid in three $1\frac{1}{2}''$ courses.

$7\frac{1}{2}''$ of macadam base laid in two courses, each course penetrated with an aphalt binder.

$6\frac{1}{2}''$ of gravel sub-base.

$18\frac{1}{2}''$ Total Thickness

The design for the rigid "concrete" pavement consisted of

10" of reinforced portland cement concrete

6" of sub-base

16" Total Thickness

The 118-mile length of the Turnpike was divided into seven sections with a total asphalt-paved area, including 2,300,000 square yards of shoulders, of approximately 6,300,000 square yards. Traffic lanes are from four to six in number depending on the intensity of traffic, with ample provision for additional lanes should this be necessary at a later date. The competitive bid prices were as shown in the following table.

COMPETITIVE BID PRICES BY SECTIONS

SECTION No.	BIDDER	ASPHALT PER SQ. YD.	ASPHALT TOTAL	CONCRETE PER SQ. YD.	CONCRETE TOTAL	ASPHALT SAVING
1	S. J. Groves & Sons Company	$6.15	$6,217,725	$7.65	$6,979,559	$ 761,834
2	Savin Construction Corp.	6.40	5,299,087	7.50	5,901,287	602,200
3	George M. Brewster & Son, Inc.	6.35	6,040,855	7.50	6,775,355	734,500
4	George M. Brewster & Son, Inc.	5.80	7,662,276	8.05	9,350,426	1,688,150
5	S. J. Groves & Sons Company	6.25	6,226,696	7.10	6,739,846	513,150
6	Tully & DiNapoli, Inc. and Gull Contracting Company	6.90	5,632,695	8.60	6,323,995	691,300
7	George M. Brewster & Son, Inc.	6.45	3,193,100	8.25	3,659,100	466,000
	TOTAL		$40,272,434		$45,729,568	$5,457,134

The work was awarded to the low bidder in all cases. In the official release of the Turnpike Authority, Chairman Paul L. Troast stated:—

"After careful consideration of all factors involving pavement, such as cost, durability and safety features, the Commissioners of the New Jersey Turnpike Authority have decided to use asphaltic concrete for the pavement of its 118-mile super-highway."

"This decision followed the receipt of alternate competitive bids on asphaltic concrete and portland cement concrete for the seven sections of our Turnpike, and after a comprehensive analysis by The Commissioners and the Authority's engineers as to the merits of both types based on all factors pertaining to pavement. Either type of pavement, incidentally, would provide an excellent highway."

"The decision was made, too, in consultation with our own engineers, and those of our special Paving Committee, who declared that the bids were sought on a comparable competitive basis, and assurances from the engineers that in using asphaltic concrete—

(1) The Turnpike will be superior to any road in existence;

(2) Asphaltic concrete will provide a substantial margin over the anticipated heaviest loads to be carried; and

(3) Asphaltic concrete will provide an excellent riding surface combining all the safety features available in any other type of highway, in all kinds of weather, and at high speeds. The asphaltic pavement, as designed, will supply a non-skid surface that is the equivalent to the best available anywhere."

Such conclusions of course are in agreement with the statements so often made by The Asphalt Institute that the *flexible base asphalt top* type of pavement can be designed to sustain present and anticipated loads adequately without failure; that it will cost less and can be built more quickly than any other comparable heavy-duty type.

THE TURNPIKE OPENS

A new transportation era dawned in New Jersey with the partial opening of its Turnpike on November 5, 1951. On that date the 53-mile length from Bordentown south carried its first toll-payers. Late in November the 60-mile stretch from Bordentown north to Newark will follow; with complete operation scheduled for January.

Concentrating Finishing Equipment on the Turnpike for accurate and speedy construction. *Photo: Spencer*

DESIGN OF THE TURNPIKE ROADWAY AND ITS PAVEMENT

PART I

By John M. Griffith

Engineer of Research, The Asphalt Institute

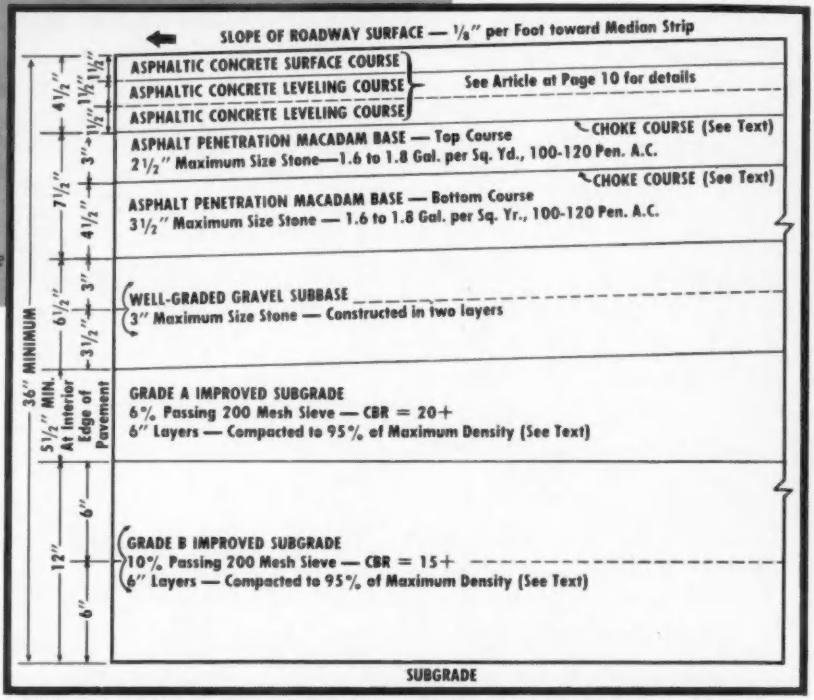


FIG. 1 TYPICAL CROSS SECTION—NEW JERSEY TURNPIKE ROADWAY

The roadway structure of the New Jersey Turnpike, designed to support adequately unlimited traffic of vehicles having single axle loadings up to 36,000 pounds, has three component parts above the natural subgrade. First, there is a zone which may be termed "improved subgrade", which is placed where required to a minimum depth of 17½ inches and is composed of materials not susceptible to frost-heaving or loss of strength due to frost action. Second, there is a 14-inch base layer composed of 6½ inches of gravel, over which is placed 7½ inches of asphalt penetration macadam. The gravel is generally referred to as the sub-base and the penetration macadam as the base. Finally, there is a 4½ inch surface of hot-mix asphaltic concrete, which will be described in Part II of this article on page 10. A typical cross section of the entire roadway structure is shown in Figure 1.

IMPROVED SUBGRADE

The principal function of the improved subgrade is to provide frost-free materials and certain minimum soil bearing qualities where the natural cut or fill materials were unsatisfactory in this respect. Provisions were made for two types of improved subgrades designated as Grades A and B.

Grade B Subgrade was placed immediately above the natural cut or fill material, and is frost-resistant, having a plasticity index not in excess of 6 and graded so that not more than 10 percent passes the 200 mesh sieve. This material has a California Bearing Ratio (CBR) of at least 15 when compacted by procedures to be noted herein.

Grade A Subgrade is placed above the Grade B material and is pervious, free draining, and frost-resistant, meeting the A-3 classification of the U. S. Bureau of Public Roads with a plasticity index of not more than 3 and with not more than 6% of the material passing a 200 mesh sieve. It has a CBR of not less than 20% when compacted by the following procedures.

In preparing specimens to determine the CBR of the material, compaction procedures outlined in American Association of State Highway Officials Test Method T99-49 were employed with the following exceptions: The mold was 6 inches in diameter by 6 inches high, the weight of rammer was 10 pounds and height of fall 18 inches; the soil was compacted in 6 layers with 55 rammer blows per layer. "Optimum moisture" was that which gave maximum density under these modified procedures and CBR values were determined in the laboratory under optimum moisture and maximum density conditions. Grade A and B Subgrade materials were compacted in the field to at least 95 percent of maximum laboratory density, determined accordingly.

In the sand fill sections crossing certain portions of the swampy area known as the "Jersey marshes", the use of improved subgrade materials was not required, since the sand fill itself fulfilled all requirements of the improved subgrades. In areas where improved materials were required, Grade B material was placed to a uniform depth of 12 inches over the general subgrade. The Grade B material was then overlaid by Grade A material varying from a compacted depth of 5½ inches at the inner edge of the inner lane to about 10 inches at the outer edge of the outer lane, thus providing a lateral slope of the roadway of about ⅛ inch per foot toward the median strip.

SUBBASE

The bottom 6½ inches of the 14 inch base layer was a gravel subbase placed in two layers and compacted to thicknesses of 3½ inches and 3 inches for the bottom and top courses respectively. Grading requirements for the subbase materials were as follows:

Square Sieve Size, *Inches*	Total Percent Passing *(By Weight)*
3	100
2	85-100
¾	50-75
No. 4	25-50
No. 200	0-5

It was further required that the selected material be reasonably uniformly graded from coarse to fine, and contain sufficient minus four material to fill the voids between the larger particles and sufficient fine material for binding.

Subbase materials were placed at or near their optimum moisture content. Compaction was accomplished by three-wheel rollers weighing not less than 10 tons and loaded to not less than 330 pounds per linear inch of contact or by rubber tired rollers or construction equipment with wheel loads of 25,000 pounds or more.

BASE

The 7½ inches of penetration macadam was placed in two courses, the top and bottom courses being 3 inches and 4½ inches respectively in compacted thickness. Aggregates for these two courses were crushed stone, graded to meet the following requirements:

TOTAL PERCENT (BY WEIGHT) PASSING

Square Sieve Size, Inches	Bottom Course Percent	Top Course Percent
$3\frac{1}{2}$	100	....
3	90-100	....
$2\frac{1}{2}$	70-95	100
2	30-60	90-100
$1\frac{1}{2}$	5-20	35-70
1	0-5	5-20
$\frac{3}{4}$		0-5
No. 200	0-2	0-2

These courses were placed in sufficient depth to provide the required compacted thickness and rolled with ten-ton or heavier three-wheel rollers having a contact pressure of not less that 425 pounds per linear inch. Asphalt cement of 100-120 penetration grade was then applied at a rate of 1.60 to 1.80 gallons per square yard. Choke stone of either ¾" or ⅝" maximum size, was then applied in sufficient quantity to fill the surface voids in the coarse stone. After spreading and brooming the choke stone, the base was rolled longitudinally and diagonally by two-wheel rollers. Rubber-tired rollers or construction equipment having *a minimum wheel load of 25,000 pounds* were then applied over the entire surface of each base layer.

A second application of 100-120 penetration asphalt cement, at a rate of 0.25 to 0.35 gallon per square yard, was then made on the upper course and, when required by the Engineer, on the lower course. This second application was covered immediately by ⅜ inch choke stone and rolled longitudinally and diagonally as for the initial choke course.

The final surface of each course was free from ruts and loose stone and true to line, grade and cross section. Deviations from a transverse template or from a 10-foot straight edge longitudinally were ⅜" or less.

In addition to grading requirements, all stone used in the base had less than 35% wear as determined by the Los Angeles Rattler Test (A.A.S.H.O. Designation T96-49) and not more than 12% loss when subjected to five-alternations of the Sodium Sulfate Soundness Test (A.A.S.H.O. Designation T104-46). The asphalt cement used in the base was of a 100-120 penetration grade meeting the requirements of A.A.S.H.O. Designation M20-42.

The completed roadway structure thus has a minimum depth of 36 inches of frost-free material, composed of successively higher bearing quality materials from bottom to top. This is the flexible base design that the Asphalt Institute has recommended for heavy-duty highways, a design more than adequate to support the large volume and magnitude of the anticipated traffic.

Laying rock for asphalt penetration macadam base

Rolling stone prior to applying asphalt

Penetrating installed base stone with asphalt
Photos: New Jersey Turnpike Authority

Asphaltic Concrete paving on the Route 35 Interchange.
Photo: Ostergaard

ASPHALTIC CONCRETE PAVING MIXES

PART II

By John M. Griffith

The New Jersey Turnpike is being paved with $4\frac{1}{2}$ inches of hot-mix asphaltic concrete, placed in three lifts. There are two lifts of leveling course mix, each of which are $1\frac{1}{2}$ inches in thickness, and $1\frac{1}{2}''$ surface course. For these paving mixes detailed specifications covering composition, quality requirements, mix preparations, and construction procedures were prepared by a Paving Committee under the Chairmanship of O. J. Porter. Important requirements include such items as wear and soundness for coarse aggregates; quality, cleanliness and durability for fine aggregates; and American Association of State Highway Officials standards for mineral filler and asphalt cement. Also included are aggregate gradations within relatively narrow limits, specifications for asphalt content and designations of mix-design procedures.

AGGREGATE GRADATION LIMITS

Aggregate gradation limits as specified for the surface and leveling course mixes are graphically shown below. It will be recognized that the Turnpike Specifications require mixes which are coarsely graded. In fact, they fall generally outside of the coarse-side limit specifications of many State Highway Departments, the Asphalt Institute Specifications and Corps of Engineers. One might perhaps suspect that such gradation limits would provide mixes open-textured and somewhat low in density. Actually such is not the case as the mixtures are capable of being compacted to a high degree of densification. This is indicated by comparing the gradation requirements with one of the theoretical curves for maximum aggregate density. A theoretical curve for $\frac{3}{4}$ inch maximum aggregate density used for this purpose is shown in comparison with the Turnpike gradation limits in Figure 2. Such theoretical curves may be computed mathematically by assuming uniform particle shapes and determining the proportions of each of several assumed sizes required to give maximum density under the most favorable arrangement. One should recognize that such a theoretical curve is based on certain assumptions not normally duplicated in the actual aggregate. Such a curve, however, may be used as a general guide to indicate approximately the aggregate grading characteristics which will provide maximum density. A comparison of the theoretical curve with the Turnpike gradation limits would thus indicate that a relative high degree of aggregate packing (high relative density) and, conversely, relatively low aggregate voids might be expected in the Turnpike mixes.

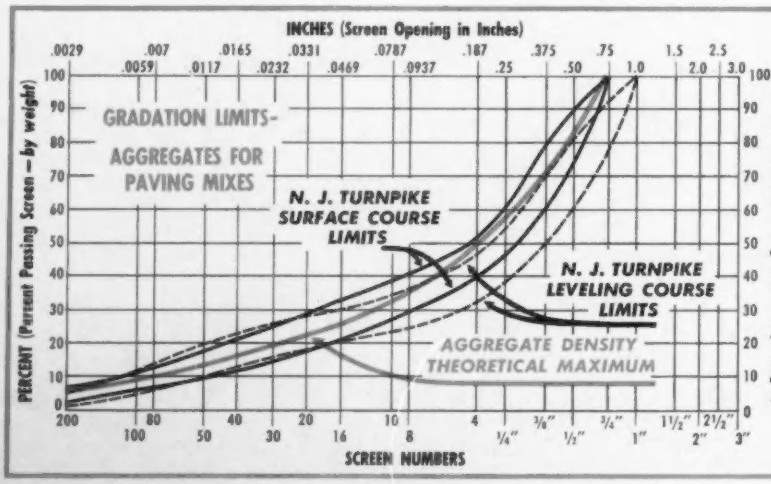


FIGURE 2

FIELD LABORATORIES

These indications have been substantiated by tests conducted in Field Laboratories which were generally established at the plant site. Laboratories were thus available for both the original design investigations and subsequent plant control operations. On one section, trailer-mounted laboratory facilities were furnished by the paving contractor. Photographs shown across the bottom of this article are illustrative of the facilities available in this trailer laboratory.

Such trailer-mounted laboratories furnish an excellent solution to the problem of designing the mix and controlling the plant production since they can be towed from one job site to another with a minimum of effort.

DESIGN AND PLANT CONTROL

Procedures formulated by the Corps of Engineers, and including the Marshall Test for stability and flow, were selected by the Turnpike Engineers as a basis for the design and plant control of the paving mixes. Briefly, these procedures require the preparation of laboratory specimens 4″ diameter by $2\frac{1}{2}''$ high under specified compaction procedures and at several asphalt contents. These compaction procedures are correlated with accelerated traffic to provide laboratory

FIELD LABORATORY: Exterior view. Trailer unit, compaction pedestal, and large sieve shaker.

specimen densities equivalent to those which occur in the pavement under traffic. Air voids, per cent of aggregate voids filled with asphalt, and density are determined for the compacted specimens which are then subjected to the Marshall Test for stability and flow. Proper interpretation of these test data indicates the most satisfactory or "optimum" asphalt content for the aggregate blend tested. These test data also provide information on the suitability of the mix at the optimum asphalt content and information on the properties of the mix at various others, as well as that determined to be optimum.

PAVING MIX PROPERTIES

The Turnpike specifications required that paving mixes at the asphalt content selected for construction have the following properties:

(a) Marshall Stability Value, as required by the Engineer. (Mixes having a Marshall Stability of 1200+ have been accepted by Turnpike Engineers)

(b) Flow Value (Marshall) not in excess of 20

(c) Density of the compacted mix to be from 92 to 96 per cent of the theoretical maximum density of a voidless mix containing the same proportions of aggregate and asphalt. In other words, the compacted mix shall have 4 to 8 per cent of air voids.

In addition to the design requirements outlined above, certain of the more pertinent material specifications are briefly summarized herewith for general information. An 85-100 penetration asphalt cement meeting American Association of State Highway Officials Designation M20-42 was required for both the leveling and surface course mixes. Coarse aggregates were specified to be of broken stone prepared from traprock, granite, gneiss, limestone or dolomite, conforming to certain quality requirements. Fine aggregates were required to be of either sand or stone screenings, or a combination thereof, also meeting certain other requirements Mineral filler was required to conform with A.A.S.H.O. Designation M17-42.

The selection of materials meeting specification requirements, laboratory investigations on the design of the paving mix and the selection of job-mix formulas for the leveling and surface course were the responsibility of the individual consulting engineer on each of the seven sections of the Turnpike. Potential material sources were investigated and laboratory tests were conducted to determine conformity with requirements as contained in the specifications, as previously outlined herein.

A tentative selection of materials meeting the various material specifications was made and design tests were then conducted on asphaltic mixtures composed of these materials. Such design tests included the preparation of specimens by designated procedures and at several asphalt contents. From these data, the optimum asphalt content was selected and the Marshall Stability, flow, density, and void relationships at the selected optimum asphalt content were determined. The job-mix formula, based on these data was then submitted to the bituminous consultants of the Turnpike Chief Engineer for approval.

CONSISTENCY AND TEXTURE

The relatively narrow spread in the acceptable gradation limits provided mixes of similar consistency and texture in all of the seven sections. Some variations in test properties of the various mixes have occurred, however, due to allowable variations in gradation and differences in type and particle shape of coarse and fine aggregates. For example, in the surface course mixes, the selected asphalt content for the various sections varies from 5.25 to 5.80 per cent; these percentages are on the so-called "added" basis wherein 5.25 to 5.80 pounds of asphalt cement are added to each 100 pounds of aggregate. Flow values of the surface course mixes were well below the allowable maximum of 20, all being in the range of 10-13.

In the the leveling course, the asphalt content varied from 4.60 to 5.30 per cent and flow values varied from 9 to 13. The widest variations in test properties of mixes from the various sections occurred in Marshall Stability Values which ranged from a low of about 1200 to a high of about 2200 in the surface course mixes and from 1300 to 2400 in the leveling course mixes. These variations are believed by the writer to be attributable principally to differences in type and particle shape of the aggregate and only to a small extent to differences in grading characteristics. In all cases, however, the stability values are considered to be entirely adequate.

CONTROL OF DENSITY

Laboratory test data indicate that the leveling course mixes in the several sections will reach 95.0 to 97.3 per cent of theoretical maximum density under traffic and that surface course mixes will reach 96.0 to 98.0 per cent of maximum density. These ultimate densities are not normally reached by the compaction of the steel-wheel rollers during construction but experience has indicated that they will be attained under the kneading action of heavy rubber-tired traffic. Thus, the pavements will be quite dense and impermeable as might have been anticipated by the comparison of the gradation limits with the curve for theoretical maximum density previously discussed. Such densities are generally within the desirable range for satisfactory dense-graded mixes although the 98.0 per cent value is slightly higher than is usually considered to be desirable. These high density values indicate, however, that the mixes contain the maximum permissible amount of asphalt cement desirable for maximum life and durability of the pavements. Also, at these asphalt contents and densities, the stability values are entirely satisfactory and flow values are well below the maximum allowed by the Specifications.

Test procedures outlined above are also being utilized as a check on plant production of the mixes. Samples of the plant mixes are taken from the trucks and tests are made to determine agreement with design requirements. In this manner, plant production meeting the design requirements is assured.

Compaction of the Test Specimens

Weighing, Testing, Sieving and Drying Facilities.

Extraction Facilities and Office Space

CONSTRUCTION DETAILS ON NEW JERSEY TURNPIKE

by Walter F. Winters
Chief Engineer, The Asphalt Institute

NOVEL COMBINATION INSTALLATION OF FO

Several unusual circumstances have combined to make the New Jersey Turnpike unique in highway construction. Possibly the greatest single factor affecting procedures was the comparatively short period of time allowed for completion. To provide this much needed highway for traffic, and to initiate returns on the $230,000,000 investment at as early a date as possible, the construction period was planned for just under two years, a very short time indeed for a project of such magnitude.

Two construction items that have had considerable bearing on methods employed are the *adverse soil conditions* found on certain sections and the *very heavy loads* to be carried by the completed pavement and bridges. In general the Turnpike parallels the coast of New Jersey, and in some places is not far distant from the ocean. This involves numerous major bridge crossings and approximately 28 miles of soft, marshy country to be traversed. Conventional single axle-loading for most highways has been 18,000 pounds, with a few states designing for 22,400 pounds. The New Jersey Turnpike, however will permit 36,000 pound single axle-loading, hence somewhat different compaction procedures were required not only for the pavement, but to insure that no undue settlement would take place over the marshy areas.

COMPACTION METHODS

The roadbed was constructed largely as an embankment. All common fill was spread in 6-inch layers to within one foot of the top and required a 90% maximum density, the upper foot requiring a 95% maximum density. The frost-free selected fill material was then placed to a thickness of 21½ inches. It too was spread in 6-inch layers to a 95% maximum density, with every needed precaution taken to obtain optimum compaction. The usual compaction methods employing moisture control, sheeps-foot rollers and steel rollers were used. In addition the subgrade was tested before placement of the gravel subbase by rolling with a special type roller having 25,000 pound wheel load on pneumatic tires. The Porter Super-Compactor was used in much of this subgrade testing. Where weak spots developed under this heavy loading, new fill material was added and the necessary support secured before the subbase layers were placed.

SAND FILLS

On the northern end of the project, where the heaviest fills were placed over marsh land, there was required some 3,000,000 cubic yards of sand borrow. The Construction Aggregates Company — Peter Kiewit Sons Company obtained this material by dredge from the approaches to New York harbor, transporting it in a semi fluid state by specially constructed barges to a slip at the Port of Newark, and from this point pumping it some 40,000 lineal feet through 20-inch spirally welded steel pipe through relay pump stations and thence to the various fill areas. This special sand borrow (at cost of about $5,800,000) provided an unusually good quality fill material over the marsh locations.

VERTICAL SAND DRAINS (Sand Piles)

The purpose and general operation of this type installation has been described at page 5, but a few details warrant further comment. Not all of the marsh areas required such treatment. Where the soft, unstable material lay in comparatively thin layers, it was stripped and replaced with granular fill. Special methods were sometimes employed in the stripping operation. For example, the Grand View Construction Company had one 90 foot fill on the approach to the Raritan River Bridge, which was constructed by filling outward into the stream after stripping just ahead of the toe of the fill using a floating dredge. This permitted easy disposal of the waste material. In general, the sand drain method appears desirable wherever muck reaches considerable depth, or where easy removal by dredging or stripping is not practicable.

PAVING OPERATIONS

Perhaps one of the outstanding achievements on this project has been the placement of the pavement, particularly that part of the structure ordinarily considered to be the surfacing itself. From the cross-section, shown at page 8, it will be noted that over the gravel subbase there is an asphalt penetration macadam base and an asphaltic concrete wearing course of 7½ inches and 4½ inches thickness respectively. By themselves these dimensions do not sound large, but when it is considered that over 4,000,000 square yards were to be so paved and that actual construction did not start until late Spring in 1951, with a completion date of November in this same year, the supply and hauling problems to be solved become apparent. The quantities included some 1,480,000 tons of stone and 14,000,000 gallons of asphalt binder for the base, plus 870,000 tons of aggregates, and 11,300,000 gallons of asphalt for the asphaltic concrete. The shoulder construction will also include approximately 1,500,000 gallons of asphalt. *This was an average for every working day of about 15,000 tons of aggregate plus shoulder stone and 160,000 gallons of asphalt. The production, transport and delivery of this tremendous volume of materials is a tribute to the contractors who did the work.*

ASPHALT PLANT INSTALLATION

Extra large hot-mix plant installations were required, in all, fifteen hot-mix plants

ATION OF FOUR HOT-MIX PLANTS *See description below, under "Asphalt Plant Installation".*

being installed for this operation. These plants have push-button control of mixing and most of them have a capacity of 120 tons of hot-mix per hour. An automatic control for weight of the aggregates was installed in each plant while control for weight of the asphalt was manually operated. Ten of the plants were installed especially for this work, while the other five, located on the northern end of the project are in fixed locations.

The Tioga Paving Company made one of the largest new installations, consisting of four large hot-mix plants capable of producing a minimum of 4,000 tons of hot-mix per day. Actually this installation has produced regularly around 5,000 tons daily, and one day put out over 6,000 tons. These four units, placed adjacent to one another, are fed from a central set of aggregate bins. These bins are kept filled from four large stockpiles containing the four different size aggregates by four belt conveyors. From this central aggregate supply the appropriate amounts for each size are metered on to another set of conveyors which carry them to the dryer of each plant. This novel arrangement allows for a flexible control of the plant operations, as one, two, three, or all four plants can be operated as may be desired with no interference of the aggregate control. Here, as in the other plants, this aggregate control has resulted in mixtures of very uniform character.

MISCELLANEOUS EQUIPMENT

In finishing the asphaltic concrete not more than ⅛-inch in 10 feet variation is allowed on the leveling courses, or ⅛-inch in 16 feet on the surface course. These tolerances are checked by inspectors using a wheeled straight-edge, on which a buzzer sounds when such tolerances have been exceeded. The straight-edge inspections follow as closely as possible the rolling operation behind the paving machine and usually the large three-axle rollers are able to correct the deficiencies noted by the inspection crews.

Several of the contractors on the Turnpike have employed short wave voice radio for more complete liaison between offices and various items of equipment in the field. The use of radio not only has simplified control of the work, but has led also to much faster operations.

On Sections 3 and 4, the contractor, George M. Brewster and Son, Inc., used a Vibro Tamper, a device manufactured by the International Vibration Company of Cleveland, Ohio, to arrange and settle the penetration base rock into position. This unit is self-propelled, is on a crawler mount, and has a tamping mechanism consisting of six independent vibrating pads in line in the front of the machine. These pads are each 2 feet wide and 16 inches long mounted on a horizontal frame. The ground contact of each shoe is 1.5 square feet and weight 300 pounds, with off-balance weights on each which provide 16 pound-inch at a vibrating speed of 2,800 r.p.m. These machines, used on the base rock behind the stone spreading machines, nested and arranged the coarse stone particles in a very excellent manner. After the baserock was vibrated it was rolled with a steel-wheeled roller and the conventional method of penetration macadam construction carried out.

In addition to the foregoing, the contractors on this project have employed all types of modern equipment, such as car shakers at stock-pile locations, the latest truck and earth-moving equipment and many other types too numerous to mention. At night great fleets of trucks were lined up in the contractors equipment yards in a manner reminiscent of the Army truck pools of the war period. Large maintenance shops, equipped with the latest types of machinery, worked night and day to keep the trucks, shovels and other equipment in top running order. Field service units were continually on the job caring for periodic maintenance and every effort made to get a full day's work out of every piece of equipment on the project.

It is doubtful if any project has ever been constructed which has employed as extensive and complete a construction organization as the New Jersey Turnpike, an organization cooperating with the Consulting and Turnpike Engineers to produce an outstanding project — one of the fine highways of the world.

Super-Compactor Testing Subgrade

Vibrating Tamper settling base rock into position

ASPHALT INSTITUTE ENGINEERS

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District Engineer at Seattle

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District Engineer at Atlanta

Rodney P. Ryker, with headquarters at 4432 White-Henry-Stuart Building, Seattle, Washington, directs the engineering and promotional activities of The Asphalt Institute throughout Oregon and Washington.

His background of training and experience includes, first, nine years with the State of Washington Highway Department. Following this initial experience, he served for ten years as a County Engineer in that state, supervising construction of roads in Kittitas and Okanogan counties. After a two year interval in private business, he was employed as Washington State Supervisor of Hydraulics, resigning in May, 1948, to accept his present position as District Engineer with the Asphalt Institute.

Mr. Ryker is a Registered Professional Engineer, a Member of the American Society of Civil Engineers, the American Society of Agricultural Engineers, the Engineers' Club of Seattle, and an Associate in the Highway Research Board.

William H. Mills, from his headquarters in the Mortgage Guarantee Building, Atlanta, Georgia serves The Asphalt Institute as District Engineer in the states of Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina and Tennessee.

For twenty-seven years, after graduating from Clemson College in 1923, his engineering career included twenty years in the South Carolina State Highway Department; five years of active duty with the U.S. Corps of Engineers, rank of Lieutenant Colonel; and then two years with the Engineering Division of the Civil Aeronautics Administration, prior to coming with The Asphalt Instititue in 1949.

Mr. Mills is a registered professional engineer in South Carolina and a member of the American Society of Civil Engineers, the American Society for Testing Materials, the Georgia Engineering Society, Past-President of the South Carolina Society of Engineers and an Associate of the Highway Research Board.

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